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HYDROUS SULPHATES FORMED UNDER FUMEROLIC CONDITIONS AT THE UNITED VERDE MINE

CARL LAUSEN.[2]

INTRODUCTION

The minerals described in this paper are the result of a fire that has been burning in the mine of the United Verde Copper Company, at Jerome, for a number of years. According to Robert E. Tally[3] the first fire started in the fall of 1894, on the 300 ft. level, and was the result of a cave in the Hampton ore body. Much of the ore contains abundant pyrite, and the specific gravity of this mineral is high. The collapse of this stope, together with the consequent friction produced by the fragments of ore in settling, may have raised the temperature of the mass several degrees; but, undoubtedly, spontaneous combustion was a more important factor in starting the fire. In recent years stripping operations with steam shovels have exposed the still hot rocks impregnated with these minerals.

These sulphates, therefore, have formed so recently, some within a few months, that one might justly question the propriety of calling them minerals; but as they are the result of natural processes it is certainly just as reasonable to consider them as minerals as are those that are now forming around hot springs.

ACKNOWLEDGMENTS

The writer is under obligations to Mr. Robert E. Tally, General Manager of the United Verde Copper Company for permission to publish the results of this investigation; and to Dr. F. N. Guild, Professor of Optical Mineralogy at the University of Arizona for considerable help with the crystal measurements and the determination of the optical properties. The analyses of the minerals were

[1] Published by permission of the Director of the Arizona Bureau of Mines.

[2] Field geologist, United Verde Copper Company.

[3] Tally, Robert E., Mine-fire methods employed by the United Verde Copper Co. *Trans. Am. Inst. Min. Eng.*, vol. 55, pp. 186–202, 1917.

made by Dr. T. F. Buehrer, Professor of Analytical Chemistry at the University of Arizona. Mr. E. D. Gardner, Supt. of the Southwestern Station of the U. S. Bureau of Mines kindly furnished the writer with the analyses of gases collected by himself and Mr. G. W. Jones.

General Geology

A brief description of the general geology and character of the ores in this mine, undoubtedly will be a help to the reader better to understand the nature of the burning material as well as the condition under which the minerals have been formed.

The ore at the United Verde Mine occurs along the edges and partly within a pyritic chimney which pitches to the northwest at a steep angle. An intrusion of diorite forms the northwest wall and appears to have localized the mineral-bearing solutions as the pyritic mass occupies an embayment in this diorite. To the south and east are schistose greenstones with more or less recrystallized sedimentary material, and these rocks have been invaded by an intrusion of rhyolite porphyry which is now also quite schistose. These rocks, as well as the ores, are pre-Cambrian in age.

Massive pyrite is the most abundant constituent of this chimney, and ore bodies in this mine often contain as much as 30 or 40 per cent of sulphur. This pyrite is fine-grained, and is intimately intergrown with quartz, together with small amounts of chalcopyrite, sphalerite, and arsenopyrite. Another type of ore is found in black schist consisting very largely of a dark green chlorite and in it the pyrite and chalcopyrite occur as irregular bands. Such ore rarely contains over 25 per cent sulphur. The copper in these ores is almost entirely in the mineral chalcopyrite although lesser amounts of tennantite and bornite are present. A little galena has also been found.

Certain portions of this pyritic chimney, especially near the diorite contact, contain irregular masses of fine-grained quartz which are locally known as jasper. Much of this quartz is white to light gray in color, but some is red or brown due to iron oxides. This quartz is thoroughly shattered and traversed by numerous cracks. Here, the sulphates developed from the burning area are most abundant, although some occur along cracks in the massive pyrite.

Methods Used to Extinguish Fires

According to Tally[4] various methods were tried to extinguish the fires. The fire areas were first flooded with water, but this procedure was not a success. Carbon dioxide was used and then steam; all however, were unsuccessful. The Plenum system was then tried and found to be effective. This consists of forcing air under a pressure of from 2 to 5 lbs. into the fire district. This air not only forced back the hot gases but also cooled the adjacent rocks. Tally[5] states that when the bulkheads were first opened, the ground was red hot, and the air forced in such an area reduced the temperature from 1200°F. (650°C.) to 120°F. (65°C.) in six weeks.

Many of the hydrous sulphates were probably formed when water was first used to put out the fires. Conditions, however, must have varied from time to time, as the various sulphates are not mutually intergrown, but rather occur as crystals of one composition resting on those of another.

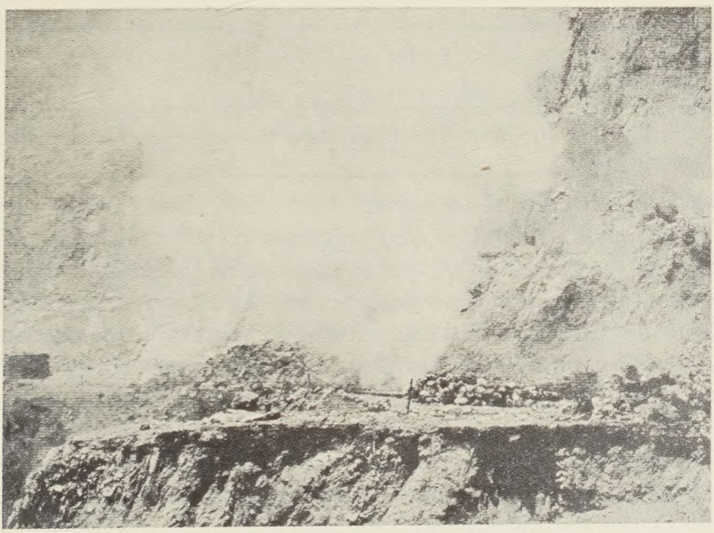


Fig. 1.

[4] *Op. cit.*, p. 187.
[5] *Op. cit.*, pp. 188–189.

Fire Gases

Considerable smoke was issuing from cracks and churn drill holes in the floor of the pit at the time these minerals were collected. Sulphur vapors rising from one of the drill holes is shown in the illustration as Fig. 1. During the latter part of 1924, five samples of these gases were collected by E. D. Gardner and G. W. Jones of the U. S. Bureau of Mines.

Table I

Analyses of Gases from the Steam Shovel Pit, United Verde Mine[6]

No.	Source of Sample	CO_2	O_2	H_2	CO	CH_4	SO_2	H_2S	N_2
1	From cracks in ground at bottom of pit	1.83	16.04	0.02	0.10	0.01	1.30	0.00	80.78
2	" " " "	4.67	11.78	0.07	0.14	0.06	1.75	—	81.53
3	" " " "	0.37	20.20	0.01	0.02	0.00	0.19	—	79.21
4	Horizontal pipe from churn drill hole	1.84	7.20	0.02	0.19	0.01	5.80	0.00	84.94
5	Vertical pipe in churn drill hole	0.94	12.49	0.01	0.10	0.00	5.90	—	80.56

The most interesting feature of these analyses is the high content of nitrogen and oxygen. and suggests a considerable admixture of air. As the ground is somewhat broken and cracked by mining operations it is difficult to collect a sample that is not contaminated with atmospheric gases. Thus, in sample number 3, the nitrogen and oxygen total over 99 per cent, and this sample is, therefore, almost entirely air. In only two samples, numbers 4 and 5, does the sulphur dioxide approach 6 per cent. Parts of the fire are in areas of stoped ground containing abundant mine timbers, and the gases of sample number 2 are probably from such an area as the carbon dioxide content is 4.67 per cent.

Large metal hoods were placed over some of the vents from which a large volume of gas was issuing, as a protection to the workmen in the pit. Later, when the interior of these hoods were examined, it was found that the sides of the hood as well as fragments of rock on the ground were coated with a thin film,

[6] Analyses by G. W. Jones, Pittsburgh Station, U. S. Bureau of Mines.

often as globules, of a shiny, dark substance. A chemical examination of this mineral shows it to be a mixture of arsenic and sulphur. A more complete description of this mineral will be found on another page.

As this dark mineral is now being deposited, it is hardly likely the hydrous sulphates described in this paper were formed from gases closely approximating in composition those given above. These sulphates were probably all formed when water was first used to extinguish the fire and the mine flooded. The gases then must have contained a large percentage of water vapor which reacted with the sulphides of iron and copper and carried these constituents to higher levels where the hydrous sulphates were deposited. It is impossible for these sulphates to have been deposited from solutions. These gases carried, in addition to water vapor and sulphur trioxide, small amounts of ferrous and ferric iron, aluminum, copper, sodium, and, at times, potassium. These metallic elements cannot have been deposited from solutions, but on the contrary were carried as gases; however, it is not definitely known whether they were transported as oxides or as molecules having the composition of the mineral as deposited.

Table II.

Analyses of Hydrous Sulphates

	1	2	3	4	5	6	7	8	9
H_2O	45.28	31.03	22.83	31.33	22.15	31.72	18.82	20.64	16.13
SO_3	37.84	38.45	38.63	39.34	39.68	44.05	46.30	47.90	47.83
Fe_2O_3	0.52	27.12	36.31	20.84	19.12	14.69	22.57	28.07	14.34
Al_2O_3	13.48	nil?	0.55	2.55	2.11	6.93	1.52	1.40	6.06
CuO	nil	2.26	nil	nil	15.78	nil	11.29	nil	—
FeO	nil	0.38	0.41	7.01	1.49	nil	nil	nil	8.82
MgO	nil	nil	nil	nil	nil	nil	nil	nil	1.55
CaO	0.19	nil	nil	nil	nil	nil	nil	nil	—
K_2O	nil	0.24	nil	nil	nil	nil	nil	0.06	4.52
Na_2O	2.06	1.74	2.73	0.88	1.23	2.13	nil	1.23	—
Total	99.37	101.22	101.46	101.95	101.56	99.52	100.50	99.30	99.25

1. Alunogen
2. Copiapite
3. Butlerite
4. Louderbackite
5. Guildite
6. Coquimbite
7. Ransomite
8. Rogersite
9. Voltaite

Analyses 1 to 8 inclusive by Dr. T. F. Buehrer.

Analysis 9 by Mr. Chas. Anderson.[7]

[7] Anderson, Chas., Voltaite from Jerome, Ariz., *Am. Mineral.*, vol. 12, p. 288, 1927.

These analyses have been arranged according to the increasing per cent of sulphur trioxide. On the basis of this constituent they may be divided into two groups; the first five are over 37 per cent and under 40 per cent while the remaining four are between 44 per cent and 48 per cent of sulphur trioxide. If the water content is used as a basis for separation into groups three stand out clearly; the first group comprises analyses 3, 5, 7, 8, and 9 and in these the water varies between 16 and 23 per cent. In group two, which includes analyses 2, 4, and 6 the water is close to 31 per cent; while the third group contains only analysis 1 with the exceptionally high water content of over 45 per cent.

In most of these minerals the ferric iron, although variable in the different minerals, is the most important metallic element; however, alunogen, analysis 1, is a straight, hydrous sulphate of alumina with only a small amount of ferric oxide. Most of these minerals are, therefore, essentially hydrous, ferric sulphates.

Of the bivalent elements copper is present as a part of the molecular constitution in guildite, analysis 5, and ransomite, analysis 7; but in copiapite the amount is only a little over two per cent, and here it is, most likely, an impurity. Ferrous iron enters into the composition of louderbackite and voltaite, while magnesia was noted only in the latter mineral. The lime in the alunogen is certainly present as an impurity.

Univalent elements found are potassium and sodium. Potash is present in three of the minerals, but only in the voltaite is it important; in the other two analyses in which it is shown, it is very likely an impurity. The persistent, though small amount of soda in nearly all these analyses is quite puzzling. To consider it as entering into the molecular composition would make the formula for some of these minerals extremely complex. In just what form the soda is present is unknown. If as an impurity, most likely as the hydrous sulphate; for it does not enter into the composition of alunogen, copiapite, and coquimbite, although present in all three of these minerals.

Extreme care was used in selecting material for these analyses. Some of the sample of each of the minerals was crushed and examined microscopically to ascertain the presence or absence of visible impurities. In louderbackite, analysis 7, a little pyrite was noted, and this was found difficult to eliminate; but as the mineral

was simply dissolved in water no pyrite should go in solution. For this reason the ferrous iron in louderbackite is believed to be a part of the molecule.

All these sulphates are soluble in cold water; some more so than others, but in boiling water they dissolve quickly. Coquimbite is the least soluble of the group. Many of them hydrolize on dissolving and give rise to a brown precipitate of ferric hydroxide.

Some of these minerals are normal salts; others are basic or acid salts. Specimens of voltaite appear to liberate sulphuric acid readily, for the paper wrapping soon turns brown, becomes brittle, and is acid to the taste. The others, apparently, appear to be perfectly stable in the dry air of the southwest.

DESCRIPTION OF MINERALS

The study of this group of sulphates shows four of them to be species previously known and catalogued, while five of them are new to science. Some of them occur as beautiful crystals, nearly symmetrical in their development, though minute in size. As these are all water soluble sulphates etched faces are common and they give a poor signal, but this etching, in part at least, was probably due to hot vapors that also deposited minerals of a later stage. It was, therefore, necessary to measure a number of crystals of each mineral to determine accurately ϕ and ρ, and also to find all possible forms existing.

The drawings of the various crystals have been somewhat idealized, chiefly to avoid increasing the number of text figures, and yet to bring out the symmetry and to show all the forms observed.

In the succeeding pages the sulphates will be described in alphabetical order followed by a description of a sulphur and arsenic compound.

Alunogen

Alunogen occurs as a crust of variable thickness suggesting that it more or less filled the cracks in which it was deposited. One piece collected was more than an inch in thickness, and, apparently, did not entirely fill the fissure in which it was deposited as the terminal faces of the crystals project beyond this edge. In none of the specimens, however, were these crystals present as single individuals large enough to be mounted and measured. They are always

intergrown, and it was found impossible to orient them on a goniometer. Crystallization was transverse to the walls of the fissure.

On breaking a specimen the color of the mineral is white and rather chalky in texture, but on examination with a hand lens the thin crystal flakes on the edge of the specimen invariably appeared to be colorless. At first this chalky appearance was thought to be due to alteration, perhaps a slight dehydration due to the rather dry climate of Arizona, but a microscopic examination of crushed fragments of this apparently opaque material showed them to be perfectly clear and colorless. The luster is pearly, especially of the thin, crystal flakes on the edge of the specimens, and to a lesser extent throughout the crystalline mass, but on a fracture surface it is vitreous.

Dana[8] gives the crystallization as monoclinic. The habit of this mineral from the Jerome locality is apparently as thin tabular crystals parallel to the clinopinacoid and elongated in the direction of the *c* axis.

One direction of cleavage is highly perfect; and, as a microscopic examination of these cleavage fragments always shows an extinction angle, this cleavage appears to be parallel to the clinopinacoid (010). A second direction of cleavage, somewhat imperfect, and at right angles to the first, may be parallel to the orthopinacoid (100). The fracture is conchoidal.

The specific gravity of this mineral was determined with the Westphal balance using methylene iodide and benzene as liquids. This method gave 1.785 as the specific gravity. This mineral is just slightly softer than gypsum and the hardness is, therefore, between 1.5 and 2.0. It is rather brittle and breaks into long, slender, cleavage fragments.

Indices of refraction were determined by using immersion liquids which were checked on an Abbé refractometer. These indices are likely to be in error as much as five points in the third decimal place. The results gave $\alpha=1.472$, $\beta=1.479$, $\gamma=1.482$. The birefringence is 0.01. Optically, the mineral is positive. The extinction angle Z to *c* is approximately 40°.

A chemical analysis shows the mineral to be essentially a hydrated sulphate of alumina, and is a normal salt.

[8] Dana, E. S., A system of mineralogy, p. 958.

ANALYSIS OF ALUNOGEN

	Percentages	Ratios		
H_2O	45.28	2.516	2.516	18.64
SO_3	37.84	0.473	0.473	3.50
Fe_2O_3	0.52	0.003	0.135	1.00
Al_2O_3	13.48	0.132		
CaO	0.19	—		
Na_2O	2.06	0.033		
Total	99.37			

The most striking feature of this analysis is the high water content. Together the water and sulphur trioxide total over 83 per cent. By comparison with the other sulphates described in this paper alunogen differs chiefly in the high percentage of alumina and the low ferric oxide content, while the reverse is true of the other sulphates. The small amount of lime shown in the analysis is undoubtedly present as an impurity. This is also essentially true of the soda; for, if the soda were an essential part of the molecular constitution, the formula would be quite complex. Calculating the molecular ratios and considering the combined alumina and ferric oxide as unity, the formula for the alunogen from Jerome corresponds fairly closely with that given by Dana, namely: $Al_2O_3 \cdot 3SO_3 \cdot 18H_2O$. The ratios would be even closer if a small amount of water and sulphur trioxide were deducted to satisfy the lime present in the analysis. This lime is probably present as the hydrous sulphate, gypsum.

BUTLERITE (NEW MINERAL)

This new mineral was found coating fragments of rock used in stope filling; and, as a cement very effectively binds these fragments together. Often, especially where the coating is thin, orange-colored crystals abound. In one specimen butlerite was found associated with copiapite, and appeared to have been formed somewhat later.

The individual crystals are seldom as much as a millimeter in length, and much less in width. Examined with a hand lens they appeared to belong to the tetragonal system, bipyramidal class, but measurements on a goniometer show them to be orthorhombic in crystallization. The crystal terminates in a sharp edge where the two dome faces *r*(101) come together. Only three forms were observed on this mineral; the pyramid *o*(111); the two orthodomes,

r(101) and *s*(302). The first two forms were observed on all the crystals measured, but the face *s* is rare. No trace was seen of the pinacoids or prisms. Several minute faces were noted near the edges and measurements show ρ to vary on these faces from 78° 15′ to 85° 10′. They are never in the proper position to correspond with a prism or pinacoid and are therefore ignored. In general, all the reflections obtained on these crystals were good.

Table III.

Crystallographic Elements of Butlerite.

Letter	Symbols Miller	Gdt.	ϕ angle	ρ angle
o	(111)	1	47° 46′	63° 43′
r	(101)	10	90° 00′	56° 42′
s	(302)	$\frac{3}{2}0$	90° 00′	66° 45′

Axial ratios $a:b:c = 0.9005:1:1.3606$.

Crystallization is orthorhombic, and a drawing of this crystal is shown as Fig. 2.

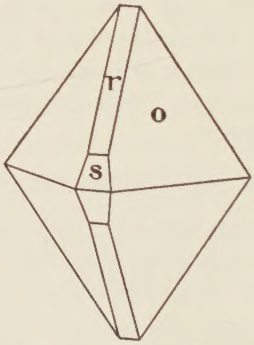


Fig. 2. Drawing of a crystal of Butlerite.

Butlerite is of a deep orange color and corresponds to OR–O, 9′–k in Ridgway's Color Standards and Nomenclature. Thin films are more nearly a pale yellow-orange. The streak is faint yellow.

One direction of cleavage is perfect and this is apparently parallel to the *b* pinacoid; the other is imperfect and also pinacoidal. The luster on a fracture surface is vitreous. Hardness about 2.5,

and the specific gravity as determined with the Westphal balance was found to be 2.548.

Optically, butlerite is negative. The indices of refraction as determined with immersion liquids checked on the Abbé refractometer are: $\alpha=1.604$; $\beta=1.674$; $\gamma=1.731$. These are probably slightly in error in the third decimal place. The mineral is slightly pleochroic; X = pale brownish yellow, Z = pale canary yellow. The birefringence is moderately high.

ANALYSIS OF BUTLERITE

	Percentages	Ratios		
H_2O	22.83	1.270		5.47
SO_3	38.63	0.483		2.08
Fe_2O_3	36.31	0.227	0.232	1.00
Al_2O_3	0.55	0.005		
FeO	0.41	0.006		
Na_2O	2.73	0.044		
	101.46			

As shown by the analysis above, butlerite is essentially a hydrous sulphate of ferric iron. The soda, although present to nearly 3 per cent, is probably an impurity; and so is the ferrous iron. Combining the ferric iron and alumina, and taking this molecular ratio as unity, the formula for butlerite is, $(Fe, Al)_2O_3 \cdot 2SO_3 \cdot 5H_2O$.

The ratio would be even closer to this formula if a small amount of water and sulphur trioxide were deducted to satisfy the soda present in the analysis.

This mineral is named in honor of Dr. G. M. Butler, Dean of the College of Mines and Engineering, University of Arizona.

An artificial sulphate having the composition of butlerite was prepared by Posnjak and Merwin.[9] On analysis this salt was found to contain: Fe_2O_3 38.50 per cent; SO_3 39.13 per cent; H_2O 22.07 per cent (by difference); and corresponds closely with the analysis of butlerite given above. They found the indices of re-refraction to be: $\alpha=1.588$; $\beta=1.678$; $\gamma=1.749$; and these are nearly the same as determined for butlerite by the writer. However, the salt prepared by Posnjak and Merwin is monoclinic in crystallization, and is stable in solutions only below 100°. It is possible that butlerite was formed at higher temperatures by vapors, and this may acount for the difference in crystallization.

[9] Posnjak, E., and Merwin, H. E., The system $Fe_2O_3-SO_3-H_2O$: *Jour. Am. Chem. Soc.*, vol. 44, pp. 1978–1979, 1922.

As shown by the gnomonic projection, butlerite is clearly orthorhombic.

Copiapite

Copiapite associated with coquimbite was found as an alteration product of voltaite at Jerome by Chas. Anderson.[10] The copiapite collected by the writer does not appear to be an alteration product, but was deposited as such along fissures in the rock. One specimen obtained consists of a crust nearly a centimeter in thickness coating hematite and limonite; and here the mineral is massive. Copiapite was found also as an aggregate of minute, thin crystalline plates, hexagonal in outline, and occupying cavities in granular pyrite associated with louderbackite. Small, rounded grains occur embedded in rogersite; and thin, bladed crystals several millimeters in length occur with butlerite.

The habit commonly observed on copiapite from this locality is as thin, pseudo-hexagonal plates parallel to $a(100)$. Microscopic examination of these flakes shows the pinacoid $a(100)$, the base $c(001)$ and a clinodome. The prismatic crystals are elongated parallel to c and flattened parallel to $b(010)$. Terminal faces are absent, and they were probably destroyed by the vapors that deposited the butlerite. These two habits are shown as Figs. 3a and 3b. The crystallization is monoclinic.

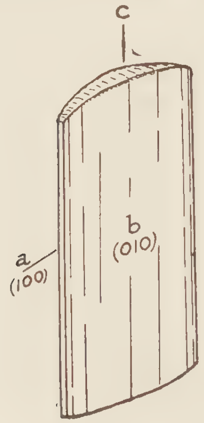


Fig. 3a

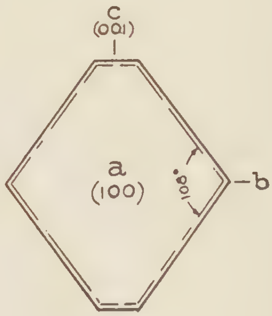


Fig. 3b

Fig. 3a. Copiapite elongated parallel to c axis

Fig. 3b. Copiapite as flat pseudo-hexagonal plates parallel to a (100)

[10] *Op. cit.*

Color is variable; in the thicker, prismatic crystals it is a deep, honey yellow; and the massive variety and the small flakes are citron. Cleavage parallel to $b(010)$ is perfect; to $a(100)$ imperfect. The fracture is conchoidal, and the luster vitreous in the smaller flakes to oily in the thicker crystals. The mineral is translucent. Specific gravity 2.092.

The mineral is biaxial. Indices of refraction, all ± 0.005, determined with oils are: $\alpha = 1.525$; $\beta = 1.540$; $\gamma = 1.595$. The mineral is pleochroic with X = canary yellow; Y = colorless; Z = greenish yellow.

Analysis of Copiapite

	Percentages	Ratios	
H_2O	31.03	1.724	10.20
SO_3	38.45	0.481	2.84
Fe_2O_3	27.12	0.169	1.00
CuO	2.26	0.028	Probably Impurities
FeO	0.38	0.005	
K_2O	0.24	0.002	
Na_2O	1.74	0.028	
	101.22		

Copiapite is essentially a hydrous sulphate of ferric iron; and, therefore, the copper, ferrous iron, potash, and soda are probably present as impurities. These impurities must be present as soluble sulphates. The molecular ratios given above are nearly 1:3:10, but if some sulphate and water is deducted to satisfy the constituents present as impurities, the ratios more nearly approach those given for copiapite by Dana, namely, $2Fe_2O_3 \cdot 5SO_3 \cdot 18H_2O$.

The physical properties also correspond with those given for copiapite.

Coquimbite

This is a well known species of ferric sulphate, and its occurrence as an alteration product of voltaite from Jerome was first described by Anderson[11] in an article published in this Journal. The material collected by the writer, however, is not an alteration product, and appears to have been deposited as coquimbite.

Coquimbite occurs as a crystal-studded lining on cavities in the broken rock. A freshly broken surface sparkles beautifully in the sunlight due to the large number of perfectly smooth crystal faces.

[11] *Op. cit.*

Generally, these crystals are attached to the wall rock by a prism face, but sometimes they are set on the base and then a complete array of small, first and second order pyramidal faces may be observed surrounding the base. The mineral was also found surrounding fragments of charred wood, and then it was beautifully banded in different shades of light gray.

This mineral was found associated with guildite in some specimens and with voltaite in others. It appears to have been formed earlier than guildite and after the voltaite was deposited.

The crystallization is trigonal, and the habit is in thin plates parallel to the base. The larger crystals are thicker and often quite symmetrical. In all, five different forms were noted, and these were found on all the crystals measured. Many of the crystals, especially where they are intergrown, show only the pyramid $d(11\bar{2}2)$ with the first and second order prisms and base. On one crystal only the base and one prism were observed. Fig. 4 shows all the forms observed on a single crystal, and the drawing is only slightly idealized.

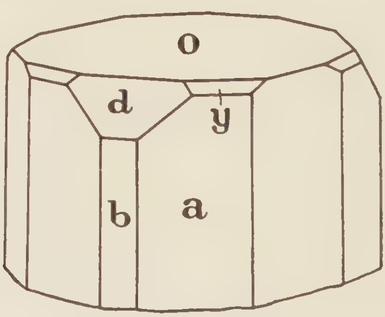


Fig. 4. Drawing of a crystal of Coquimbite from Jerome.

Table IV.

Crystallographic Elements of Coquimbite

Letter	Symbols Bravais	Gdt.	ϕ angle	ρ angle
o	(0001)	0		0° 00′
d	$(11\bar{2}2)$	½	30° 00′	58° 28′
y	$(10\bar{1}2)$	½0	0° 00′	44° 17′
b	$(01\bar{2}0)$	∞	30° 00′	90° 00′
a	$(10\bar{1}0)$	∞0	0° 00′	90° 00′

These results would give an axial ratio considerably higher than that published by Dana or Goldschmidt, but the values for the various forms are sufficiently close to establish the species beyond any doubt. This is especially true when compared with the results of a chemical analysis.

The base and prism faces gave good, clear signals, but unfortunately, this was only occasionally true of the pyramidal faces.

Coquimbite from Jerome is colorless and beautifully transparent. In the larger crystals the mineral has a faint lavender tint. This is the least soluble of all the sulphates found at this locality, but readily dissolves in boiling water. The mineral has perfect prismatic cleavage, and on a fracture surface the luster is vitreous. Hardness 2.5 to 3. Specific gravity 2.066.

It is uniaxial and optically positive. Indices of refraction determined with oils are $\epsilon = 1.572$; $\omega = 1.536$ and are probably slightly in error in the third decimal place. The birefringence is moderate.

Analysis of Coquimbite

	Percentages	Ratios		
H_2O	31.72	1.762		22.02
SO_3	44.05	0.551		6.89
Fe_2O_3	14.69	0.092	0.160	2.00
Al_2O_3	6.93	0.068		
Na_2O	2.13	0.034		
	99.52			

Soda is here clearly an impurity. An interesting feature of the analysis is the alumina, which, in this case, is nearly half the ferric iron. Combining the molecular ratios for alumina and ferric iron and considering this value equal to two, the formula for this mineral becomes, $2(Fe, Al)_2O_3 \cdot 7SO_3 \cdot 22H_2O$.

This corresponds with the composition of coquimbite given by Dana.

Guildite (new mineral)

This new mineral is relatively rare and occurs as individual crystals varying in size up to one-half centimeter in width. It is closely associated with both coquimbite and ransomite.

At first glance these crystals appear to be cubes, and the crystallization isometric, but a careful examination shows the base

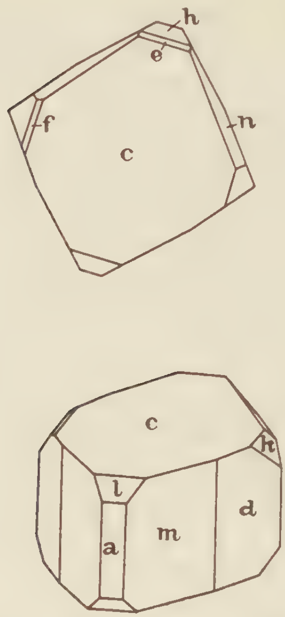


Fig. 5. Idealized drawing of Guildite.

to be inclined to the prism face. The monoclinic crystallization and symmetry was definitely established by measuring the crystals. A total of 10 different forms were found. These are the base *c*(001); front pinacoid *a*(100); the unit prism *m*(110); a second prism *d*(540); clinodome *k*(011); a plus and a minus orthodome; a pyramid; and two small curved forms. Although a number of crystals were measured, on none was a trace found of the side pinacoid *b*(010). The plus orthodome *l*(101) does not fall in the correct position on the gnomonic projection, and ρ for this face is probably between 2° and 3° below the theoretical value. An interesting feature of this mineral are the prisms. They never occur together; either the crystal has developed the unit prism faces *m*(110) or else the prism *d*(540); and the pyramid *n*(346) occurs along with the latter.

In the table below no values are given for ϕ and ρ for the two domes *e* and *f*. These are small curved faces, and the reflections obtained suggest the symbol for *e* to be ($\bar{1}02$) and for *f* (012).

TABLE V.

CRYSTALLOGRAPHIC ELEMENTS OF GUILDITE

Letter	Symbol Miller	Gdt.	ϕ angle	ρ angle	Remarks
c	(001)	0	90° 00′	15° 17′	
a	(100)	$\infty 0$	90° 00′	90° 00′	
m	(110)	∞	44° 55′	90° 00′	
d	(540)	$\infty \frac{4}{5}$	38° 35′	90° 00′	
k	(011)	01	11° 15′	55° 07′	
l	(101)	+10	90° 00′	56° 29′	error 2–3°
h	($\bar{1}01$)	−10	90° 00′	48° 33′	
n	($\bar{3}46$)	$-\frac{1}{2},\frac{2}{3}$	25° 20′	46° 44′	
e	($\bar{1}02$)	$-\frac{1}{2}0$	variable	variable	curved face
f	(012)	$0\frac{1}{2}$	"	"	" "

Axial ratio $a:b:c=1.037:1:1.407$, $\mu=74°43'=180-\beta$.

As a rule, the signals from these crystals were poor and it was found difficult to center the blurred image. Five crystals were measured to obtain a fair average value for m, and two crystals to determine $d(540)$. Almost invariably, the base gave a group of closely spaced images. This, together with the poor reflections from the prism caused considerable trouble in properly aligning the crystal on the goniometer. The domes and the pyramid, when present, gave clear, sharp images. An idealized drawing of a crystal of guildite is shown as Fig. 5.

Guildite, in the larger crystals, is a deep, chestnut brown color, somewhat lighter in the smaller ones, and corresponds to 13″ m in Ridgway's color standards. Thin cleavage flakes are honey yellow, and the streak is pale, canary yellow. Crystals are translucent and cleavage fragments transparent.

Two directions of cleavage, both perfect, are present in this mineral; one is parallel to the base (001) and the other parallel to the front pinacoid (100). The fracture is conchoidal, and the luster vitreous. This mineral is quite brittle. Hardness about 2.5; and the specific gravity, as determined with the Westphal balance, was found to be 2.725.

Optically, guildite is positive. Indices of refraction determined with immersion liquids are: $\alpha=1.623$; $\beta=1.630$; $\gamma=1.684$; all

± 0.005. The birefringence is 0.061. The mineral is quite pleochroic; X = pale yellow, Y = pale yellow, Z = greenish yellow.

Analysis of Guildite

	Percentages	Ratios		
H_2O	22.15	1.231		17.46
SO_3	39.68	0.496		7.03
Fe_2O_3	19.12	0.120	0.141	2.00
Al_2O_3	2.11	0.021		
CuO	15.78	0.198	0.219	3.11
FeO	1.49	0.021		
Na_2O	1.23	0.020		
	101.56			

Chemically, guildite is a hydrous sulphate of copper and ferric iron. Ferrous iron is isomorphous with copper oxide and alumina with ferric iron. Soda is probably an impurity. Combining the molecular ratios for alumina and ferric oxide and considering this unit equal to two, the formula for guildite becomes, $3(Cu, Fe)O \cdot 2(Fe, Al)_2O_3 \cdot 7SO_3 \cdot 17H_2O$.

This is a complex, hydrous sulphate containing both the RO and the R_2O_3 radicals.

The mineral is named after Dr. F. N. Guild, Professor of Optical Mineralogy, and head of the Department of Geology at the University of Arizona.

Louderbackite (new mineral)

This mineral occurs as a thin crust, a few millimeters in thickness, coating massive, granular pyrite. It is relatively rare. Associated with it is copiapite as small, yellow flakes. Louderbackite, however, was formed later than copiapite. The mineral is crystalline, but no individual crystals were found that could be measured.

The color is pale chestnut brown in the thicker crusts, and corresponds to 11''–m in Ridgway's tables; colorless in thin slivers. The streak is white. Luster oily to vitreous; translucent to transparent. Hardness 2.5–3; specific gravity 2.185 determined with Westphal balance. Two directions of cleavage were noted, both good, and apparently pinacoidal.

Louderbackite is biaxial, and optically positive. It is not pleochroic. Indices of refraction, all ± 0.005, determined with immersion liquids are: $\alpha = 1.544$; $\beta = 1.558$; $\gamma = 1.581$. Crushed fragments always give parallel extinction and the mineral is orthorhombic in crystallization.

Analysis of Louderbackite

	Percentages	Ratios		
H_2O	31.33	1.741		35.52
SO_3	39.34	0.492		10.04
Fe_2O_3	20.84	0.131	0.156	3.18
Al_2O_3	2.55	0.025		
FeO	7.01	0.098		2.00
Na_2O	0.88	0.014		
	101.95			

Chemically, louderbackite is a hydrous sulphate of both ferrous and ferric iron with a small amount of soda, probably present as an impurity. The presence of 7 per cent of ferrous iron is interesting. Although the mineral sometimes incloses small grains of pyrite the ferrous iron could hardly have been derived from pyrite as this sulphate is soluble in cold water. Dr. Buehrer took particular pains in separating the pyrite, both quickly and thoroughly, and the ferrous iron must, therefore, be considered a part of the molecular constitution. Considering the ferrous iron as unity and doubling the ratios, the formula for this mineral becomes: $2FeO \cdot 3(Fe, Al)_2O_3 \cdot 10SO_3 \cdot 35H_2O$.

This sulphate is named after Dr. Geo. D. Louderback, Professor of Geology, University of California.

Ransomite (new mineral)

Ransomite occurs as crusts lining cavities in the crushed rocks and also as small tufts of radiating crystals. It is often associated with guildite and was formed somewhat later. Crystallization was transverse to the walls, and the unfilled space is often lined with well-developed, slender crystals showing abundant terminal faces. These minute, needle-like crystals are rarely more than a few millimeters in length.

The crystallization is orthorhombic, and the habit is as slender prisms elongated parallel to the *c* axis. Ransomite is rich in forms,

and ten in all were found by measuring five crystals. In no case were all the forms noted on a single crystal, and the drawing of a crystal of ransomite, Fig. 6, is highly idealized. This was done chiefly to avoid extra text figures. Very often the crystals terminated in a broad, inclined face, the dome *d*(301); and between this form and the prisms were found the small pyramidal faces. These crystals then appeared to have monoclinic symmetry. In another type the vicinal face *r* terminated the crystal.

Table VI

Crystallographic Elements of Ransomite

Letter	Symbols Miller	Gdt.	ϕ angle	ρ angle	Remarks
o	(111)	1	30° 01′	30° 48′	
s	(211)	21	49° 40′	38° 17′	
t	(311)	31	59° 53′	45° 43′	
d	(301)	30	90° 00′	41° 15′	
e	(053)	$0\frac{5}{3}$	0° 00′	41° 13′	
a	(100)	$\infty 0$	90° 00′	90° 00′	
b	(010)	0∞	0° 00′	90° 00′	
m	(110)	∞	30° 01′	90° 00′	ϕ from unit pyramid
n	(210)	2∞	49° 40′	90° 00′	ϕ from pyramid (211).
r	—	—	variable	2° 55′	vicinal face

Axial ratios $a:b:c = 1.7407:1:0.5168$

As will be noted in the above table three pyramids occur on ransomite; two domes; two pinacoids; two prisms; and a vicinal face *r*. The base (001) is not present. No symbols are given for the face *r* as ϕ varies from 7° 30′ to 18° 33′ while ρ is constant at 2° 55′. This is probably a vicinal face. The signals were good from all faces except in the prism zone. In this zone a continuous band of light was noticed, generally faint, but with bright spots here and there. These bright spots correspond to the broader prism faces. The fainter portions may be due partly to internal reflections from the back side of the crystal, but are also due to a series of very narrow faces between prominent prisms or pinacoids, which, because of their extreme narrowness behave as a diffraction grating and diffuse the light.

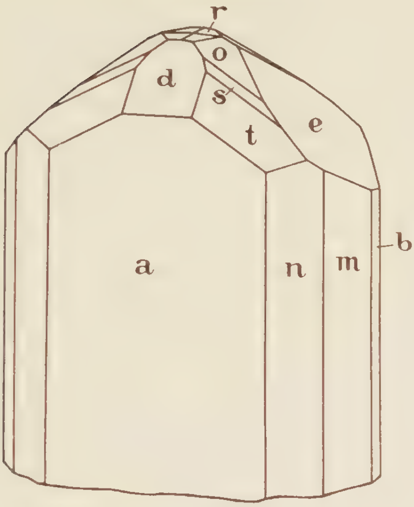


FIG. 6

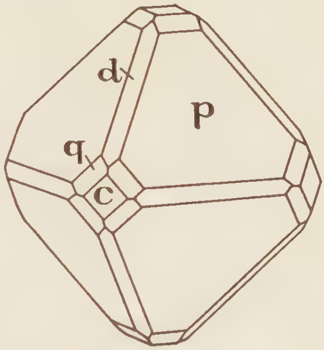


FIG. 8

FIG. 6. Idealized drawing of Ransomite.
FIG 8. Idealized drawing of Voltaite from Jerome.

On plotting the position of the more prominent prism faces it was found they did not fall in the same zone of the base and corresponding pyramid. The average value for ϕ is always larger than it should be. These relations are shown in the gnomonic projection as Fig. 7. In this figure the solid lines indicate the theoretical position and the dotted lines the position of the faces actually measured. Where a dotted line is of double length it indicates that two faces from two different crystals have the same value for ϕ. Fig. 7 is a composite of the projections of five different crystals.

The reason for this discrepancy is not readily apparent, and if due to distortion, such distortion could have been caused only by internal stresses on cooling, as the mineral was formed near the surface in free space.

The color of ransomite is a bright sky blue and corresponds closely to 41′-f in Ridgway's color standards. The mineral is transparent in the smaller crystals and the luster is pearly on a cleavage face to vitreous on a cross fracture. The cleavage is perfect and is either pinacoidal or prismatic. Specific gravity 2.632; hardness 2.5.

Ransomite is optically positive and biaxial. The indices of refraction, all ± 0.005 are: $\alpha = 1.631$; $\beta = 1.643$; $\gamma = 1.695$.

ANALYSIS OF RANSOMITE

	Percentages	Ratios		
H_2O	18.82	1.046		7.36
SO_3	46.30	0.578		4.07
Fe_2O_3	22.57	0.141	0.167	1.12
Al_2O_3	1.52	0.015		
CuO	11.29	0.142		1.00
	100.50			

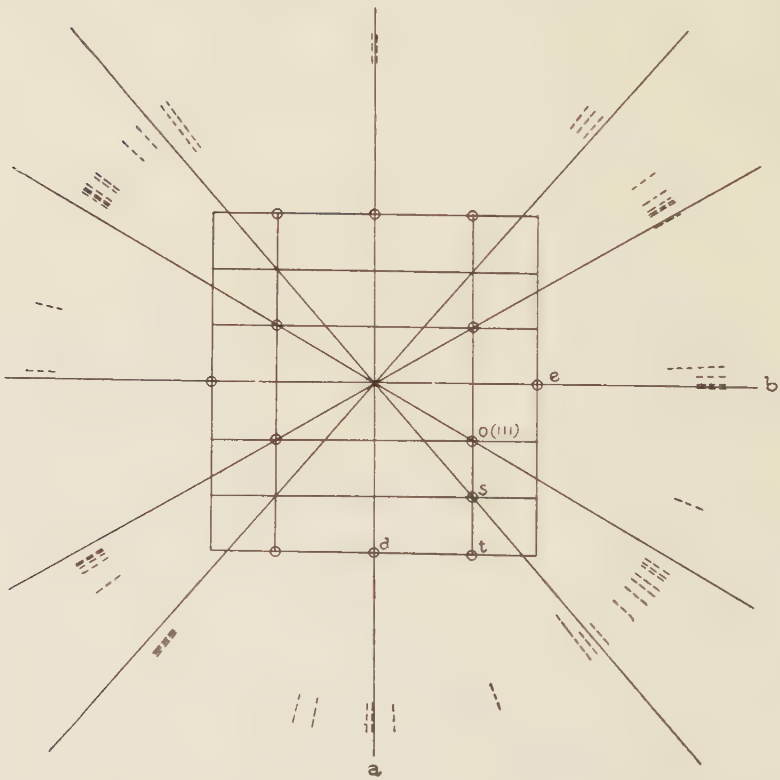


FIG. 7

FIG. 7. Gnomonic projection of Ransomite. Composite of five projections. Prism faces shown by dashed lines. See text for discussion.

Chemically, the mineral is a hydrous sulphate of ferric iron and copper, and a small amount of alumina is isomorphous with

ferric iron. With the molecular ratio of copper oxide as unity, the formula for ransomite becomes: $CuO \cdot (Fe, Al)_2O_3 \cdot 4SO_3 \cdot 7H_2O$.

This mineral is named in honor of Dr. F. L. Ransome, Professor of Economic Geology at the California Institute of Technology, and formerly of the University of Arizona and the United States Geological Survey.

Rogersite (new mineral)

Large lumps of a white color and consisting of an aggregate of minute, silky fibers were found associated with other sulphates at this locality. Embedded in these lumps are small, rounded grains of copiapite. Qualitative tests showed this white material to be a soluble sulphate of ferric iron and it is a new mineral.

The individual fibers or crystals when examined microscopically were found to be colorless and transparent. They are never as much as one half millimeter in length and are too small to be measured on a goniometer. It is not certain that terminal faces would have been found even if this were possible.

Because of their small size it is possible to determine but a few of the physical properties. No cleavage was noted although one or more directions of cleavage may be present. The luster of the aggregate is silky; and, if the individual crystals could be examined, this property might be vitreous. Efforts to determine the specific gravity gave unsatisfactory results; the minute fibers remaining suspended for hours in liquids having different specific gravities. The hardness is unknown.

Optical tests show the mineral to be monoclinic in crystallization and elongated parallel to the *c* axis. The indices of refraction as determined with immersion liquids are: $\alpha = 1.598$; $\beta = 1.628$; $\gamma = 1.654$, all ± 0.005.

The maximum extinction angle α to c is 27°.

Analysis of Rogersite

	Percentages	Ratios	
H_2O	20.64	1.147	6.03
SO_3	47.90	0.599	3.15
Fe_2O_3	28.07	0.176 } 0.190 =	1.00
Al_2O_3	1.40	0.014 }	
K_2O	0.06		
Na_2O	1.23	0.020	
	99.30		

As may be readily seen from the above analysis, rogersite is a hydrous sulphate of ferric iron. Both soda and potash in this analysis are believed to be present as impurities. The mineral differs from the other sulphates described in this paper both in physical properties and chemical constitution. It is a new mineral species, and is named after Dr. Austin F. Rogers, Professor of Mineralogy at Stanford University, and past president of the Mineralogical Society of America.

An artificial ferric salt prepared by Posnjak and Merwin[12] corresponds closely in both composition and optical properties with rogersite. This salt formed slender, colorless laths, monoclinic in crystallization with an extinction angle α to c between $22°-26°$. The indices of refraction given by these writers is: $\alpha=1.605$; $\beta=1.635$; $\gamma=1.657$. They state the salt crystallizes readily and is stable in contact with its saturated solution from somewhat above 50° to 150°C.

Voltaite

Voltaite from this locality has been described by Mr. Chas. A. Anderson[13] in an article published in this Journal. Only a brief description, therefore, will be given here.

Most commonly, the mineral occurs at this locality as an aggregate of small crystal grains. Some good crystals, however, were found and measured. They are octahedrons with the dodecahedron on the edges and the cube on the ends. The trapezohedron $q(112)$ was noted on one crystal. Fig. 8 is an idealized drawing of voltaite from this locality.

The color is black in crystals and thin fragments under the microscope have a greenish tint. The luster is vitreous to oily. The specific gravity was determined with the Westphal balance and found to be 2.611. Index of refraction $n=1.594$. The crushed powder when examined under crossed nicols exhibits very weak double refraction.

The alteration of voltaite to copiapite and coquimbite as noted by Anderson does not occur in the material collected by the writer. This is probably due to the drier climatic conditions existing at Tucson where the specimens have been kept for some time.

[12] *Op. cit.*
[13] *Op. cit.*

MINERALS ASSOCIATED WITH THE HYDROUS SULPHATES

Sulphur

Sulphur appears to be in process of formation at the present time. Table I, on a preceding page, gives analyses of the gases issuing from churn drill holes and cracks in the rock. Very likely, some sulphur is being deposited below the surface from these gases.

This mineral was not observed in the steam shovel pit by the writer, but specimens were obtained by geologists of the United Verde Copper Company several years ago. The sulphur occurred as an aggregate of loose crystals filling a crack in the jaspery quartz.

An examination of these crystals with a hand lens showed the terminal faces to be replaced by a blunt, rounded end, suggesting that perhaps the mineral had been partly fused after it formed. The prismatic faces are well developed, but none of the crystals were measured.

Jeromite (new mineral)

A black, globular substance occurs as a coating on fragments of rock beneath iron hoods placed over vents from which sulphur dioxide gases are issuing. Qualitative tests show this substance to be a sulphide of arsenic containing some selenium.

The mineral is opaque, but the thin edges of slivers are translucent and of a cherry red color. The fracture is conchoidal, and the luster on this fracture-surface is adamantine, suggesting a high index of refraction. Crushed fragments examined microscopically were found to be isotropic, and the mineral is apparently not crystalline. The surface of these thin crusts appears as a fused mass of globules.

Associated with the globular masses are minute crystals consisting of octahedrons, translucent to transparent, and of a yellowish to orange color. They, too, are isotropic, and when measured were found to be isometric in crystallization. Not enough of the crystalline material was available for an analysis, but qualitative chemical tests show them to be a compound of arsenic and sulphur.

It is, therefore, possible that the rock fragments were originally coated with these orange-colored crystals and later fusion of these

crystals formed the dark substance which is amorphous in appearance. During fusion selenium may have been liberated from combination with either arsenic or sulphur, and the dark reddish color of jeromite may be due to this element.

Analysis of Jeromite[14]

	Percentages
Sulphur	40.8
Selenium	7.5
Tellurium	Trace
Arsenic	46.8
Antimony	Trace
Insoluble	4.9 (by difference).
	100.0

The mineral is soluble in boiling nitric acid, and the insoluble residue is probably finely divided particles of silica. If the analysis is recalculated free of this insoluble matter the percentages of sulphur, selenium, and arsenic are as follows:

	Percentages	Ratios	
Sulphur	42.9	1.34	2.18
Selenium	7.9	0.10	
Arsenic	49.2	0.66	1.00
	100.0		

Combining the selenium with sulphur, with which it is most closely related chemically, the ratio of arsenic to sulphur becomes nearly one to two. The formula for this mineral would then become $As(S, Se)_2$. If the sulphur is divalent and carries two negative charges the arsenic would then be tetravalent. In most of its compounds where arsenic is the positive element the valence is generally three or five.[15] But the above formula is an empirical one, and if the ratios are doubled so as to read $As_2(S, Se)_4$, then the arsenic would be pentavalent as indicated in the following structural formula:

[14] Analysis by Dr. T. F. Buehrer.

[15] Smith, Alex., General chemistry for colleges: p. 582, 1921.

$$
\begin{array}{l}
\mathrm{S} \\
\| \\
\mathrm{As}=\mathrm{S} \\
| \\
\mathrm{As}=\mathrm{S} \\
\| \\
\mathrm{S}
\end{array}
$$

Here one of the bonds of arsenic is assumed to be connected with another atom of arsenic. This, however, is purely hypothetical. More work will be required before this fact can be established.

The mineral is named after the city of Jerome near which it occurs; and, as here used, is applied only to the dark substance which appears to be amorphous.

THE PROBABLE IDENTITY OF CAMSELLITE WITH SZAIBELYITE*

WALDEMAR T. SCHALLER, *U.S. Geological Survey, Washington, D.C.*

Szaibelyite, from Hungary, was described in 1861 and analyses published a few years later. Although not so stated, the "secondary fibrous mineral" associated[1] with ludwigite at Philipsburg, Mont., is probably the same. In 1921, camsellite from Canada was described[2] as a new mineral. In April 1925 Eakle described[3] camsellite from California and in June, the same year, szaibelyite was described[4] from Nevada.[5]

The occurrence of the Hungarian szaibelyite was again mentioned by Koch in 1888 (abstr. in *Zeitschr. Kryst. Min.*, vol. **17**, p. 505, 1890) and its optical properties given by Loew in 1911 (abstr. in *Zeitschr. Kryst. Min.*, vol. **54**, p. 181, 1914) as follows: Parallel extinction, negative, $\epsilon = 1.59$, $\omega = 1.65$. Slavik in 1917 (see *Zeitschr. Kryst. Min.*, vol. **60**, pp. 162, 163, 170, 1924) and (in French) in 1918 (Données optiques sur quelques minérals: *Bull. Internat. Acad. Sci.*, Boheme, **1918**) gave[6] the properties, parallel extinction, uniaxial?, elongation negative, $\epsilon = 1.575$, $\omega = 1.60$. Larsen, in *U. S. Geol. Survey Bull.* **679** (1921) quotes Loew's values.

* Published by permission of the Director, U. S. Geological Survey.

[1] Schaller, W. T.; Mineral. Notes, Series 1. *Bull.* **490**, *U. S. Geol. Survey*, p. 28, 1911.

[2] Ellsworth, H. V., and Poitevin, E.; Camsellite, a new borate mineral from British Columbia, Canada. *Trans. Royal Soc. Canada, Sect. IV, Ser. III*, vol. **XV**, p. 145, 1921.

[3] Eakle, A. S.; Camsellite from California. *The American Mineralogist*, vol. **10**, p. 100, 1925.

[4] Gillson, J. L., and Shannon, E. V.; Szaibelyite from Lincoln County, Nevada. *American Mineralogist*, vol. **10**, p. 137, 1925.

[5] The associated needle-like unknown mineral has the optics of ascharite, another hydrous magnesium borate. Gillson (priv. com.) called attention to its more probable identity with fluoborite, as suggested by Geijer. The formula of ascharite, $2MgO \cdot B_2O_3 \cdot {}^2/_3H_2O$, is very close to that of szaibelyite (camsellite) but the indices (Larsen) are considerably lower, instead of higher, as they would be expected to be with less H_2O. The composition and properties of ascharite need restudy. The possible presence of fluorine in these magnesium borates must be considered.

[6] The reference in *Zeitschr. Kryst. Min.*, vol. **60**, has ϵ and ω interchanged.

If, now, the optical properties of szaibelyite and camsellite, as given in the literature, be tabulated, it can readily be seen that they are not only very close but practically identical. The value of $\omega(=1.60)$ given by Slavik is the only discordant value and is probably a little low.

Comparison of Optical Values of Szaibelyite and Camsellite

Mineral	Locality	Extinction	Elongation	Sign	Character	ϵ	ω
Szaibel-yite	Hungary, Loew	Parallel	—	negative	—	1.59	1.65
	Hungary, Slavik	Parallel	negative	—	Uniaxial?	1.575	1.60
	Nevada	Parallel	—	negative	Uniaxial	1.575	1.650
Cam-sellite	Canada	Parallel	negative	—	(a)	(α) 1.575	(γ) 1.649
	California	Parallel	negative	—	—	(α) 1.580	(γ) 1.651

(a) For the original camsellite (from Canada)it is stated that the fibers are flattened parallel to the axial plane and it is suggested that the mineral is orthorhombic. 2V is thought to be probably very large although no axial figure was seen. β was not determined. The statement in Dana (p. 878) that szaibelyite is optically biaxial is not verified by the other determinations (Loew, Slavik).

A comparison of the analyses shows a similar composition, although the presence of silica in several of the samples analyzed, complicates the comparison. Eakle considers the silica as essential to the camsellite from California, whereas Ellsworth and Poitevin consider all the silica in the Canadian sample to be due to admixed serpentine. In the following comparison of analyses, both these occurrences are given twice, that from California, first (column 5) with the silica as given by Eakle, and second (column 6) with the silica omitted and the analysis recalculated to the same total. For the Canadian camsellite, the analysis is first given (column 7) with only the admixed dolomite deducted and the analysis recalculated to 100 per cent and second (column 8) with both the dolomite and serpentine (based on the silica content) deducted and the analysis recalculated to 100 per cent. If there is no silica in the Canadian camsellite, then column 8 represents the composition of the analyzed mineral. If any silica belongs to the mineral, then its composition would be represented by values between the figures given in columns 7 and 8. The last column, No. 9, gives the calculated composition according to the formula $2MgO \cdot B_2O_3 \cdot H_2O$. Columns 1, 2, 3 are the analyses of szaibelyite from Hungary, as given by Dana and Hintze. Column 4 is the analysis of szaibelyite from Nevada. All other elements present, mostly less than one per cent, are grouped together under X. Probably all the samples (except possibly the mineral from California) were admixed with other substances, whose allocation is not attempted but which are grouped together under X. The interpretation of the silica present

in the camsellite from California is not attempted but the evidence afforded by the analysis of material from other localities suggests that its presence may be interpreted in other ways than that it is an inherent part of the mineral. The close relationships to sussexite likewise suggests that the silica does not belong to the mineral.

COMPARISON OF ANALYSES OF SZAIBELYITE AND CAMSELLITE

	Szaibelyite				Camsellite				
	Hungary			Nevada	California		Canada		Calc.
	1	2	3	4	5	6	7	8	9
SiO_2	—	0.20	—	4.83	7.16	—	8.57	—	—
MgO	54.65	52.49	49.44	46.72	46.07	49.62	44.00	44.59	47.87
FeO	—	—	—	—	2.46	2.66	—	—	—
B_2O_3	38.35	36.66	34.60	31.22	33.34	35.91	32.57	41.24	41.44
H_2O	7.00	6.99	12.37	9.87	10.94	11.78	11.07	10.47	10.69
X	—	2.15	3.40	7.36	—	—	3.79	3.70	—
	100.00	98.49	99.81	100.00	99.97	99.97	100.00	100.00	100.00

Colums 1, 2, 3. Analyses are given in Dana and Hintze.
Colum 4. Analysis as given. B_2O_3 by diff.
Column 5. Analysis as given.
Column 6. Same as 5 with silica deducted.
Column 7. Analysis with only admixed dolomite deducted.
Column 8. Analysis with both admixed dolomite and serpentine deducted.
Column 9. Calculated composition for formula $2MgO \cdot B_2O_3 \cdot H_2O$.

Considering not only the similarity of the analyses as given above, but also the practical identity of the optical properties, it seems reasonable to conclude that the two minerals szaibelyite and camsellite are probably the same. The name szaibelyite has priority by many years. The confusion regarding the solubility of the mineral in acids still needs clarification; perhaps the degree of fineness of the fibers has not been sufficiently considered.

THE OCCURRENCE OF LEUCOXENE IN SOME OF THE PERMIAN MID-CONTINENT SEDIMENTS

Levi S. Brown, *University of Texas.*

The mid-continent sediments referred to in the title are found in South Central Oklahoma. The formations strike due north and south, and for considerable distances across the strike are alternately sandstones and shales. All are Permian in age, and prevailingly red in color.

In the course of a petrographic study of the sandstones, carried on during the past two years, leucoxene was found in considerable abundance. The universal distribution of titaniferous minerals, especially ilmenite and rutile, renders the occurrence of leucoxene in any locality of relatively small moment. However, the unusual amounts occurring in these sediments presented peculiar opportunities for further study, and it is hoped that the ensuing descriptions may be valuable diagnostics of its detrital varieties.

A word is necessary concerning the laboratory treatment to which the sands were subjected. Disintegration of the sands and solution of the ferruginous material coating the grains was effected by boiling with 20 per cent. hydrochloric acid, ten to twenty-five minutes being necessary for clarification. After drying, the heavy minerals were concentrated by suspension in bromoform (sp. g. 2.863), the average crop being a little less than 1 per cent. Of this crop, from 35 to 78 per cent. was made up of leucoxene. Unaltered ilmenite and rutile were also present, the former from 2 to 7 per cent. and the latter from 2 to 5 per cent. These percentages are derived from grain counts of microscopic fields.

The grains of leucoxene appear in a great variety of forms. They are rounded grains or irregular masses, white, yellowish white, to deep reddish brown in color, and may be solidly one color or a mixture of colors, distributed in regular or heterogeneous fashion. Often the grains are tabular and laminated, possessing alternately light and dark colors. Sometimes there are two sets of laminations, the traces forming two sets of fine lines, intersecting at about 60°. Occasionally laminations of unaltered ilmenite appear.

"Pitted" surfaces are common. Milner[1] says, "a rough, 'pitted' surface is characteristic of most grains." I am not sure just what

[1] Milner, H. B.; Sedimentary Petrography, (1922) pp. 59–60.

type of pitting Professor Milner has in mind. These grains exhibit minute openings or spaces within the grain itself, the perforations sometimes extending completely through the grain. In shape, the openings may be hollow spherical, thin lenticular, or acicular. They may appear in regular design or in almost any disorder, though it is to be noted that irregular arrangement is confined to equidimensional openings. The lenticular and acicular openings are always with their longer diameters parallel, but may be closely spaced or liberally separated. Sometimes there are two, or even three, sets of these openings, which appear, on flattened surfaces, as fine striations, and these invariably intersect at about 60°. The other type of pitting is that of a very rough, "flecked" surface. It is apparently due to attrition, but whether in transport or due to laboratory treatment is not clear. The many small flakes of leucoxene found evidently result from this comminution.

I believe some basis for classification of the varieties of leucoxene can be found in the texture or structure exhibited. In all of the foregoing varieties the mineral is amorphous, or so finely divided as to appear so. In another type the structure is microcrystalline, the acicular microlites being clear, light yellow in color. These are arranged in parallel masses, and grouped into bundles. Again, invariably two, and sometimes three, sets may be discerned, these intersecting at 60°, resembling a very compact sagenite.

While these two types of structure may include all varieties, it is to be noted that all gradations between the two may exist. Both types may be present in the same individual, and in any proportion.

As an alteration of ilmenite and rutile, leucoxene may be spoken of properly as a pseudomorph after these minerals. On account of the ready alteration of these minerals, one to the other, it is not always easy to say from which of the two the leucoxene in sediments was derived. If unaltered cores could be seen, it might leave no doubt, in special instances, but these do not often appear. In the few cases here observed, the core was usually of rutile, but this can not be accepted as a criterion for all. However, a knowledge of the occurrences and structures in which ilmenite and rutile may occur is a valuable aid in identifying the form assumed by the leucoxene.

Pure ilmenite and pure rutile alter to the cream-white, opaque, seemingly-amorphous material so commonly described as leu-

coxene. But pure ilmenite is rarely found. Its associates are universally magnetite and hematite. With either of these it seems to exist in isomorphous relationship, within narrow limits. Without these limits the minerals crystallize separately in those varied structures previously described by Professors Warren,[2] Watson and Taber,[3] Singewald,[4] and Hussak,[5] which structures, or patterns apparently are largely controlled by the ilmenite rhombohedron. Basal flakes (and thin sections or polished surfaces studied and recorded in the literature referred to) therefore plainly exhibit trigonal symmetry, and the 60° angles observed. It is probable, also, that with abundant magnetite the octahedron may become prominent, and here again the traces of intersecting faces are at 60° angles.

In the laboratory treatment with hydrochloric acid, magnetite is dissolved out, ilmenite is insoluble, and hematite slowly or difficultly soluble; and the resulting structures in leucoxene are replicas of those descriptions of the original ores above quoted. The "pits" previously described are solution cavities formerly occupied by magnetite. The red coloration in some leucoxenes, according to Rosenbusch, has been shown by Cathrein to be "due to the mechanical mixture of rutile in the form of sagenite, which already existed intergrown with the ilmenite." But the dark-colored grains here give no evidence of such a structure. The red color strongly suggests disseminated hematite, whose difficult solubility is in harmony with this conclusion, and the structures observed are entirely in accord with Professor Warren's descriptions of hematite-ilmenite intergrowths.

[2] Warren, Charles H.; On the Microstructure of Certain Titanic Iron Ores; *Econ. Geol.*, Vol. **13** (1918) p. 419.

[3] Watson and Taber; *Bulletin No.* **III-A**, *Virginia Geol. Survey.*

[4] Singewald, J. T., Jr.; *Bulletin* **64**, *U. S. Bureau of Mines.*

[5] Hussak, E.; *Neues Jahrb. Min. Geol. Paleon.*, Vol. **1**. 1904, p. 94.

CONSTITUENTS OF DIAMOND-BEARING BLACK SANDS FROM ANGOLA, PORTUGESE WEST AFRICA

O. F. Poindexter, *Case School of Applied Science, Cleveland, Ohio.*

The sands were taken from along the Kasai, Tangatshimo, Tshikappa, and Tulua Rivers in Portugese West Africa, and were sent to Case School a number of years ago by F. M. Rapp, a former student.

The entire sample weighing about twenty pounds was carefully gone over and the diamonds picked out by hand. This can be readily done without the use of a lens, even for the smallest diamonds. A total of twenty one small diamonds weighing 0.1353 grams or 0.68 carats, was secured. The largest diamond weighs 0.0115 grams or 0.06 carats. This latter is a clear white stone and is an almost perfect dodecahedron.

In form the diamonds are simple octahedrons, parallel growths of same and twins after the spinel law. Also simple dodecahedrons with rounded faces, combinations of the octahedron and dodecahedron, and the octahedron and the trisoctahedron. Also cleavage pieces and irregular fragments. As to color there are ten whites, five yellows, four browns and two greens. Mr. Rapp states that at the time of collection there was no commercial use for the material. It was not made clear whether or not the sands have been artificially concentrated, but they are believed to be in the natural state.

Other minerals present are as follows.—

Quartz—abundant, mostly grains, a few crystals observed.

Garnet—probably pyrope, abundant, no crystals observed.

Cyanite—abundant, bluish blades up to 4 mm. in length.

Diallage—abundant, long barrel-shaped grains resembling corundum. Longest 1.5 cm. Some of the grains show about 90° cleavage. This is readily obtained upon crushing. The barrel shape is probably the result of wear.

Corundum—(ruby) plentiful, occurs as rose red, lustrous grains. One blue grain possibly sapphire was observed but no determination was made on it.

Tourmaline—(black) rare, only one crystal was positively identified. This crystal is 2 mm. long, striated vertically and with typical cross section.

Hornblende—one crystal, 3 mm. long, the angles were not measured.

Staurolite—rare, several crystals observed. Longest 6 mm.

Zircon—rare, one crystal, 2 mm. long observed.

Rutile—plentiful, striated tetragonal crystals.

Ilmenite—abundant, constitutes practically all of the black metallic material. Non-magnetic.

Hematite—sparingly, many appear to be roughly octahedral and are probably after magnetite. The specular variety is also present.

Pyrite—a few irregular grains and partial cubes.

No especial determinative methods were applied to the majority of the above minerals since they are common constituents of such sands. Determination being based upon physical characters and crystal form. Microscopic examination was made on cyanite, diallage and corundum, and chemical tests were made on the ilmenite, rutile and hematite.

Grains suggesting the following were picked out but no determinations were made because only one grain of each was secured, spinel, columbite, beryl, topaz. Feldspars and various types of of chalcedony are undoubtedly present, also possibly opal.

The most abundant and most interesting mineral present in the sand has not been listed above. This is a black, glassy substance with a conchoidal fracture and resembles obsidian. This material makes up probably from 65 to 75 per cent of the sand and constitutes about 90 per cent of the black minerals.

As yet no analysis has been made so that no definite statement can be made as to what the mineral is.

Dr. Vincent L. Ayres in an unpublished thesis describes an "Obsidianoid Augite" from Rice, Arizona, to which the material is somewhat similar in its physical and optical properties. The mineral scratches glass easily and is scratched by quartz with great difficulty. This agrees with Ayres's 6.5 hardness for the "obsidianoid augite." Specific gravity is 3.70 as against Ayres's 3.38. Cleavage is very rarely observed even in crushed material under the microscope.

Under the microscope the mineral is colorless to brownish, depending upon the thickness of the fragment. The colored fragments are distinctly pleochroic in yellowish and brownish tones. The optical character is positive. The indices are somewhat higher than those indicated by Ayres, ranging from 1.74 to 1.76 (Becke Method). Ayres gives the following,— $\alpha = 1.708$, $\beta = 1.714$, $\gamma = 1.731$. The "obsidianoid augite" is less strongly colored in thin fragments and is non-pleochroic.

Comparing the physical and optical properties with those of the "obsidianoid augite," it seems very possible that the black mineral of the diamond sands may be a variety richer in iron. The higher indices, greater specific gravity, deeper color and pleochroism would lend support to this supposition.

A further report upon this mineral will be made when an analysis has been made.

NOTES AND NEWS

HALITE AND GLAUBERITE CAVITIES AND INCLUDED MINERALS FROM CENTRAL NEW JERSEY

A. C. HAWKINS, *Rutgers University.*

The mineral occurrences here noted are all in red shales of the Triassic series, which outcrop along the course of the Raritan river in Middlesex County, and of the Millstone river in Somerset County, New Jersey.

Massive red shales, which are weathering along the roadside just at the west end of the Johnson estate along the river road on the north bank of the Raritan a mile above New Brunswick, have afforded to date two excellent casts of halite crystals. Both of these are hopper shaped, over 2 cm. across the open end and 3 cm. deep, one showing a small cube face at the acute end. These cavities are entirely empty, the halite having long ago been removed by circulating water. They are interesting not only from the nature of their occurrence, but because there is no record of such halite crystal cavities having been found previously in this formation at any point south of Massachusetts.[1]

Cavities similarly representing glauberite crystals have often been observed near New Brunswick and elsewhere, but the remarkable abundance of them in the red shales has apparently not been recognized. At a point a mile east of New Brunswick, these slot-shaped cavities (with diamond-shaped outline, the crystals showing base *c* and unit pyramid *s*), averaging 1×1 cm. in size, so completely fill certain layers of shale that these layers are quite porous. In the vicinity of the Johnson & Johnson works in New Brunswick, and again on the east side of the river in Highland Park, the cavities, which are abundantly bunched together in what were once groups of glauberite crystals in mud layers, are lined with small white calcite crystals whose form is a combination of the obtuse rhombohedron *e* with the unit prism *m*. Also many of the cavities contain, with the calcite, white tabular barite crystals showing numerous lines of "phantom" growth. The forms shown by these barite crystals are: base *c*, unit prism *m*, unit brachydome *o*, obtuse macrodome *d*(102), and brachypinacoid *b*. The largest crystal recently found measured 1.5×2 cm. Some are arranged in rosettes. Their origin is thought to have been in hot solutions associated with those which produced the deposits of copper minerals that exist in the immediate vicinity. Similar deposits of barite on a larger scale exist at Glenmoore, N. J., and in Prospect Park, Paterson.

At the little quarry along the Delaware and Raritan canal just east of the bridge at Blackwell's Mills, the filling of calcite crystals (scalenohedral in habit) lining the glauberite cavities is so complete and firm that the shale on the outside breaks away from the cavity fillings, so that we obtain complete calcite pseudo-

[1] B. K. Emerson, A Mineralogical Lexicon of Franklin, Hampshire, and Hampden Counties, Massachusetts; *U. S. Geol. Survey, Bulletin* **126**, p. 144, 1895; Skeleton halite cubes replaced by calcite. See also Wherry, E. T., *Am. Mineral.*, **1**(3), p. 37, 1916; Describes exactly similar glauberite cavities and pseudomorphs from Pennsylvania.

morphs after the glauberite crystals. These pseudomorphs may be picked up out of the loose, weathered shale. They average 1 to 3 cm. long by 1 to 2 cm. wide, but some very large simple crystals occur, 10 cm. × 5 cm. and larger. As above stated, their forms are all very simple, showing base *c* and pyramid *s*. Numerous bunches of crystals also occur. These cavities may have been filled by the action of solutions from the dying activity of the diabase dike which is exposed in the canal bank about a quarter of a mile away to the north, which broke vertically across the shale beds, bringing in copper minerals, and soaking some of the shale layers with hot reducing solutions so that their color was changed to gray.

This Blackwell's Mills locality is six miles north of the famous Griggstown copper mine, whose minerals had a similar origin. Pseudomorphs of calcite after glauberite have also been found near New Brunswick, but rarely.

RECENT ACQUISITIONS FOR THE MINERAL COLLECTION OF THE BRITISH MUSEUM (NATURAL HISTORY)

L. J. Spencer, *British Museum, Mineral Department.*

Fine Crystals of Gem Minerals

Beryl (aquamarine), a clear bluish-green crystal of gem quality, 13 cm. high and 10–12 cm. in diameter, weighing 2505 grams (=12,525 carats). From a pegmatite on Pingueira Mountain, near Santa Rita de Arassuahy, Minas Novas district, State of Minas Geraes, Brazil. The well developed crystal (forms *m*, *a*, *c*, *p*, *s*, *u*, Dana's letters) shows beautifully marked etch-figures on the faces and the edges are slightly rounded by corrosion. It was evidently in the process of re-solution.

Topaz, a clear transparent crystal with pale blue tinge of color, measuring 12×11 ×10 cm. and weighing 2290 grams (=11,450 carats or just 5 pounds). From a pegmatite at Tsaratanana, Maevakanana district, Madagascar. The well developed and brilliant crystal faces (forms *c*, *m*, *l*, *y*, *f*, *X*, *u*, *i*, Dana's letters) are marked by complex and intricate pyramids and lines of growth, and the specimen is an instructive example of a crystal in which the process of growth has been abruptly arrested.

PROCEEDINGS OF SOCIETIES

THE MINERALOGICAL SOCIETY (ENGLAND)

Mineralogical Society, March 20th,—Dr. G. T. Prior, F.R.S. President, in the chair.

Mr. A. F. Hallimond: *On the atomic volume relations in certain isomorphous series, II.* The volume-relations of compounds of Ca, Sr, Ba with O, S, Se, and Te correspond in every way with those previously indicated for K, Rb, Cs, Na, Li, and the halogens. The differences in volume produced by the interchange of eutropic elements exhibit a constant ratio in each series. The partial volumes calculated for the radicles from the volumes of the free metals agree with those already obtained for the alkali compounds, and the values 6 for oxygen and fluorine agree with those calculated by Wasastjerna from the refractive indices. The volume effect of substitution in the sodium chloride lattice varies somewhat with the size of the cell, but the variation never attains the extent required for a

law of constant radii. Other isomorphous series agree with the Law of Retgers, and the present results are therefore expressed in terms of a law of additive volumes rather than additive radii.

PROF. A. HOLMES and DR. H. F. HARWOOD: *The age and composition of the Whin Sill and the related dikes of the north of England.* The rocks of the Whin Sill and its associated dikes are quartz-dolerites. Chemical analyses show that they are all of substantially identical composition. Dikes of this series run north of east. They are quite distinct from the system of tholtiite dikes to which the Bingfield dike, the "Brunton type" of Teall, belongs. A pebble of quartz-dolerite in the Upper Brockram of George Gill, Brackenber Moor, near Appleby, has been proved by chemical analysis to be definitely of the Whin Sill type. This, with other evidence, indicates that the age of Whin Sill and its associated dikes is post-Westphalian and pre-Upper Brockram.

MR. A. W. GROVES: *The identification of dumortierite in grains; dumortierite in Cornish granite.* Attention is drawn to the possibility of confusing dumortierite with a number of more common minerals. Dumortierite is recorded in several sediments in southern England and in the Land's End granite.

DR. T. V. M. RAO: *On "bauxite" from Kashmir, India.* The so-called bauxite of Kashmir is found to consist mainly of disapore and an opaque mineral corresponding in composition to a monohydrate of alumina. The deposit was derived from beds of clay, having been first altered into the di-hydrate (bauxite) and subsequently to its present condition through dehydration and thermodynamic metamorphism.

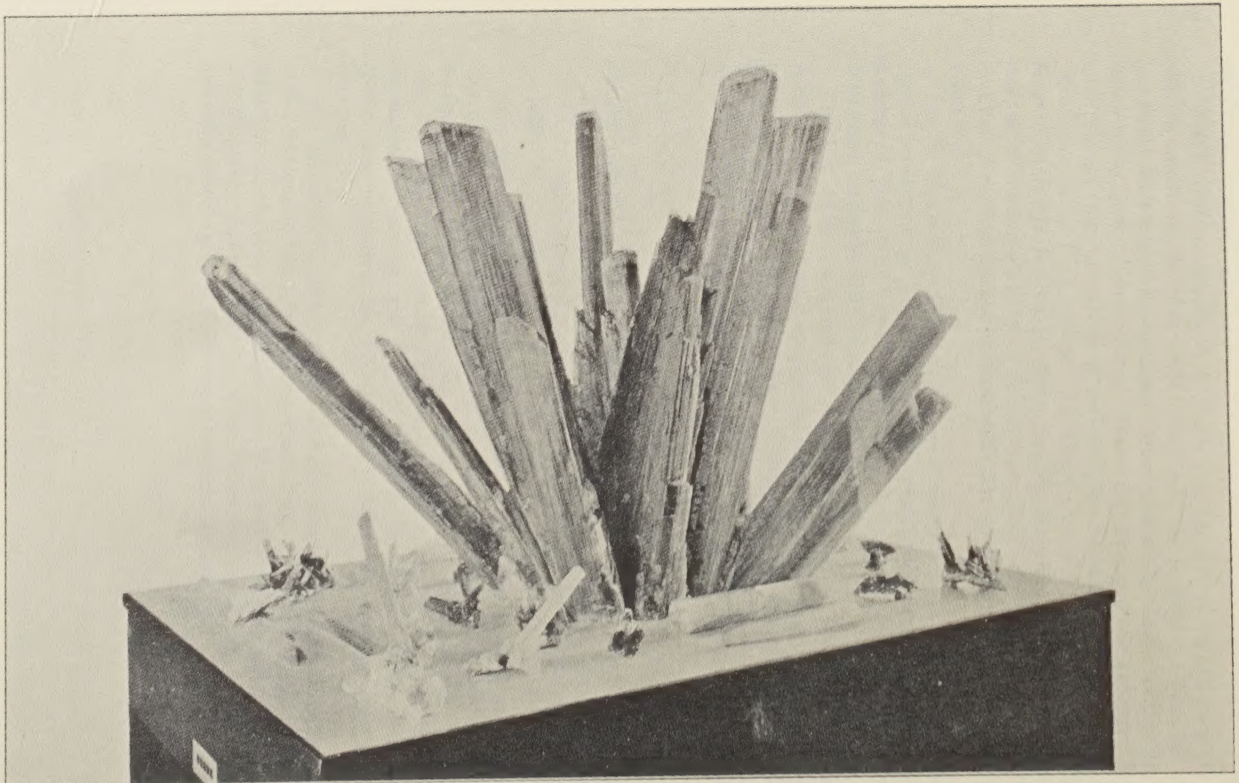
REVIEWS

CRYSTALLOGRAPHIC TABLES FOR THE DETERMINATION OF MINERALS. Victor Goldschmidt and Samuel G. Gordon. Special Publication No. 2. *The Academy of Natural Sciences of Philadelphia.* 70 pages. Price $1.50. 1928.

The authors have arranged the recorded crystallographic data of minerals according to the polar elements p_0, q_0, r_0, λ, μ, ν, as these values are obtainable by measurement. Available data for 759 minerals are given in nine tables while supplementary tables include 22 amorphous minerals, 242 for which the data are incomplete or wanting, and 2 liquid minerals. In addition to the 1025 mineral species thus accounted for, 192 doubtful species and varieties have also been included.

The possibility of selecting more than one position was also considered and the tables arranged to cover the various orientations. In order to facilitate the determination, the chemical composition, specific gravity, hardness and other characteristic properties are likewise given. These tables should prove extremely serviceable especially where fairly well developed crystals are involved.

W.F.H.



Group of gypsum crystals from Naica, Chihuahua, Mexico. This group has just been installed in the Mineralogical Museum of Harvard University. It is the same group, a photograph of which was published in this Journal, vol. **12**, p. 252, 1927, in an article by Dr. Foshag. The largest crystal is between four and five feet in length. The small crystals are from other parts of the cave.